

ARMY RESEARCH LABORATORY



Moisture Absorption of Coated Composite Materials

by Melissa A. Klusewitz, Christopher P. R. Hoppel,
Steven H. McKnight, and James F. Newill

ARL-MR-508

March 2001

20010502 101

Approved for public release; distribution is unlimited.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5066

ARL-MR-508

March 2001

Moisture Absorption of Coated Composite Materials

Melissa A. Klusewitz, Christopher P. R. Hoppel,
Steven H. McKnight, and James F. Newill
Weapons and Materials Research Directorate, ARL

Abstract

Moisture diffusion measurements were made for coated and uncoated composite materials. Two substrates were used: T650/1914-4 (a graphite fiber reinforced thermoset epoxy) and AS4/Ultem (a graphite fiber reinforced thermoplastic polymer). The specimens were tested uncoated and coated with three polymer coatings—MIL-P-53030 Primer, Humiseal 2A53, and 2031 Siloxirane. The coatings generally absorbed more moisture than the specimens and increased the total moisture absorption for the coated parts. For the AS4/Ultem bars, anisotropic diffusion constants were measured, and diffusion occurs in the fiber direction three times faster than transverse to the fibers.

Contents

List of Figures	v
List of Tables	vii
1. Introduction	1
2. Materials	1
3. Experimental Technique	3
4. Results	4
5. Conclusions	7
6. References	9
Distribution List	11
Report Documentation Page	29

INTENTIONALLY LEFT BLANK.

List of Figures

Figure 1. Photograph of the T650/1914-4 plate showing the CARC MIL-P-53030 coating on both sides of the thin four-ply plate.....	2
Figure 2. Photograph of the AS4/Ultem bar with the Siloxirane coating on one side.	2
Figure 3. AS4/Ultem bar with the Siloxirane coating on one side showing a region where the cutting process pulled the composite material over the coating region..	3
Figure 4. Moisture absorption in T650/1914-4 plates at 35 °C and 98% RH.	5
Figure 5. Moisture absorption in AS4/Ultem disks at 35 °C and 98% RH.....	5
Figure 6. Moisture absorption in T650/1914-4 plates at 50 °C and 98% RH.....	6
Figure 7. Moisture absorption in AS4/Ultem disks at 50 °C and 98% RH.....	6
Figure 8. Moisture absorption in AS4/Ultem compression molded bars at 50 °C and 98% RH.....	7

INTENTIONALLY LEFT BLANK.

List of Tables

Table 1. Specimens used in the present study.....	3
Table 2. Testing results.	8

INTENTIONALLY LEFT BLANK.

1. Introduction

This experimental study investigates the moisture absorption of composite material specimens with and without polymeric coatings. The results obtained here will be used to establish material diffusion constants and validate moisture diffusion models being developed for coated and uncoated composite materials [1].

2. Materials

Two types of composite materials were used for this study – T650 graphite fiber reinforced 1914-4 epoxy (a thermoset composite system) and AS4 graphite fiber reinforced Ultem (a thermoplastic composite system). These materials have been investigated in several previous studies on moisture absorption [2, 3]. The T650/1914-4 samples were cut from a thin, autoclave-cured four-ply panel. The panels were 1.5 in \times 2.75 in \times 0.02 in; the fibers were lying in the 1.5 in \times 2.75 in plane so that moisture diffusion would occur primarily in the direction transverse to the carbon fibers. The AS4/Ultem samples were manufactured by two methods: bars cut from a thick compression-molded panel, and disks cut from a composite preform manufactured by compression molding. The bars were made with two orientations so that anisotropic diffusion coefficients could be measured. They were made in the fiber direction and transverse to the fibers. The disks were cut from a preform transverse to the fiber direction so that diffusion would be predominately in the fiber direction.

Three coating materials were investigated – Humiseal 2A53 coating, Siloxirane, and an Army CARC MIL-P-53030 primer. The coating materials were sprayed onto the test specimens. The coating thicknesses were measured after the moisture tests were concluded. The samples were sectioned using a Struers, Inc. accutom saw. The freshly cut edge was examined under a Leitz Wild stereomicroscope, model 420, at a nominal 320 \times power. The samples were mounted in the staging area of the microscope using either a putty type material, or they were held in place by two plastic blocks such that measurements were made perpendicular to the cut surface. The samples were photographed at intervals of 0.2 in using a Hitachi HVC20 digital camera in conjunction with an Oculus-TCI Demonstration Software Program, Version 3.01 by Conco, Inc. These photographs were downloaded to a PC with an Ultra Plus II video capturing board and stored on the hard drive as a tiff file. Thickness measurements were then made using the software, Scion Image, Beta 4.02 by

Scion Corp. To correctly analyze these images, the scaling was set 420 pixels to equal 1 mm. The distance from the inner edge to the outer edge of the coating was measured using a cursor drop function (Figures 1 and 2). In regions where the saw pulled composite material into the coating, no measurements were taken (Figure 3). A full description of all of the test specimens is given in Table 1.

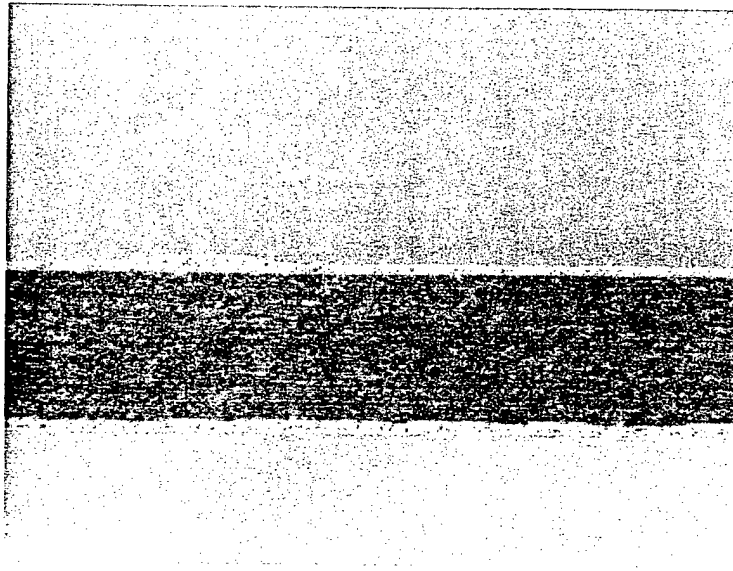


Figure 1. Photograph of the T650/1914-4 plate showing the CARC MIL-P-53030 coating on both sides of the thin four-ply plate.

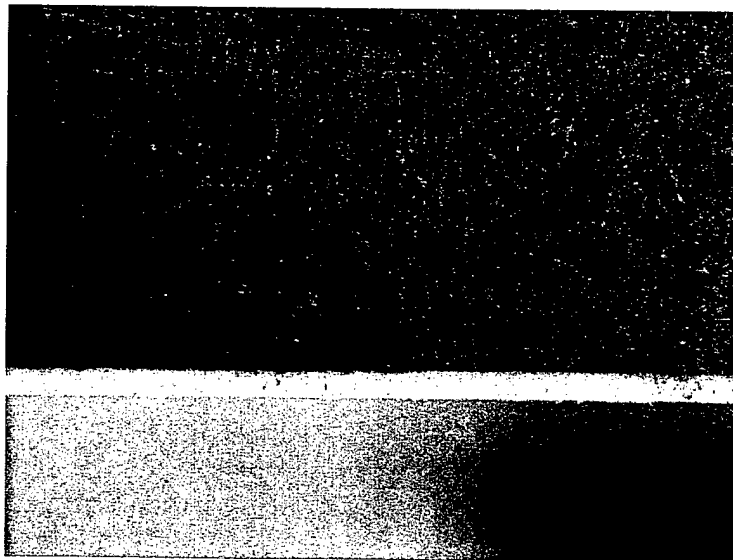


Figure 2. Photograph of the AS4/Ultem bar with the Siloxirane coating on one side.



Figure 3. AS4/Ultem bar with the Siloxirane coating on one side showing a region where the cutting process pulled the composite material over the coating region. This occurred after the moisture test, when specimens were being prepared for coating measurements; no measurements were made in this region.

Table 1. Specimens used in the present study.

Substrate	Diffusion Direction	Coating	Coating Thickness (in)	Standard Deviation
T650/1914-4 Plates	Transverse to fibers	Primer	0.00098	0.0007
T650/1914-4 Plates	Transverse to fibers	None	0	—
AS4/Ultem Disks	Fiber Direction	None	0	—
AS4/Ultem Disks	Fiber Direction	Primer	0.00125	0.0004
AS4/Ultem Bars	Fiber Direction	None	0	—
AS4/Ultem Bars	Fiber Direction	Humiseal	0.00104	0.0003
AS4/Ultem Bars	Fiber Direction	Siloxirane	0.00232	0.0007
AS4/Ultem Bars	Transverse to fibers	None	0	—
AS4/Ultem Bars	Transverse to fibers	Humiseal	0.00104	0.0003
AS4/Ultem Bars	Transverse to fibers	Siloxirane	0.00232	0.0007

3. Experimental Technique

All of the specimens were thoroughly dried in a vacuum oven prior to testing. For testing, all samples were placed in a constant temperature-humidity chamber. The samples were evenly distributed in a steel mesh tray to ensure

uniform airflow around all specimens. Two test conditions were used: (1) 35 °C and 98% relative humidity (RH) and (2) 50 °C and 98% RH. Prior to testing, the specimens were weighed daily for the first 10 days of the test and every other day until the conclusion of the test.

4. Results

The moisture weight gain vs. time for the test specimens are shown graphically in Figures 4–8. Diffusion coefficients were calculated for each specimen from equation 1, as specified by ASTM Standard D 5229/D5229M-92 [4],

$$D = \pi \left(\frac{h}{4M_m} \right)^2 \left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \right)^2, \quad (1)$$

where h is the specimen thickness, M_m is the moisture saturation level, and the quantity in the second set of parentheses is the slope of the initial linear region on a plot of moisture weight gain vs. the square root of time. This initial linear region is normally taken to be 60% of the time required for saturation. Diffusion coefficients were calculated for all of the samples, even though they are not really appropriate for the coated samples (higher order analysis is necessary for the two-part systems and will be described in a subsequent study [5]). For the present study, these diffusion constants were calculated simply for comparison purposes. The reduced experimental data is listed in Table 2.

From the results it is important to note the anisotropic nature of diffusion in the composite materials. For the uncoated bar specimens, the diffusion rates are on the order of three times higher in the fiber direction as opposed to transverse to the fibers. This agrees with results found in the general literature [6]. This means that moisture will absorb much more quickly in composite structures with exposed fiber ends (normal to the surface) than in structures with fibers parallel to the surfaces.

The results reported here should be viewed as laboratory data. The coating thickness is relatively thick as compared to the small specimens. The experimental results will be used to validate theoretical models in a separate study. However, it is interesting to note that the coatings generally increased the maximum moisture contents and the diffusion coefficients as compared to the uncoated substrates.

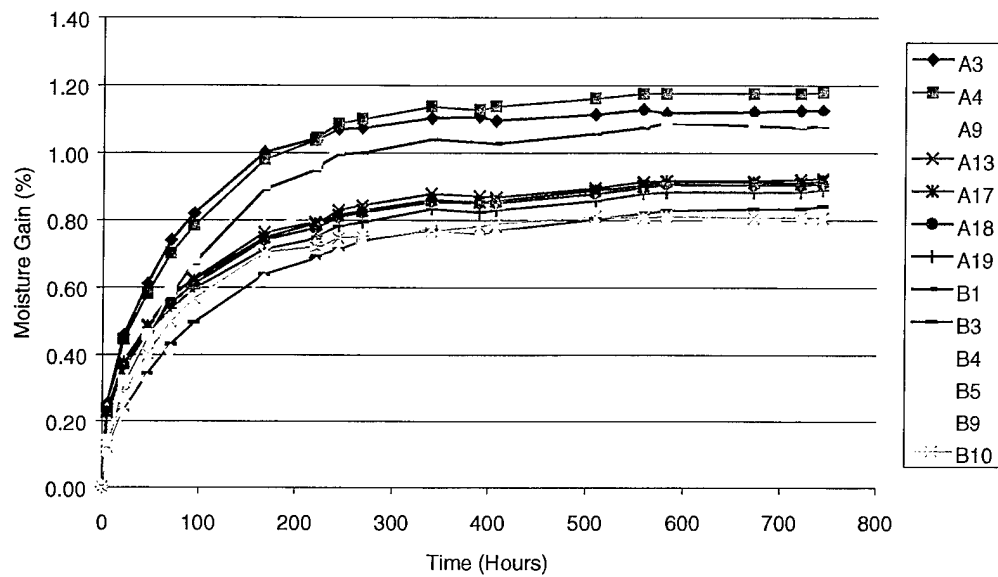


Figure 4. Moisture absorption in T650/1914-4 plates at 35 °C and 98% RH. Group A had the primer coating, and group B had no coating.

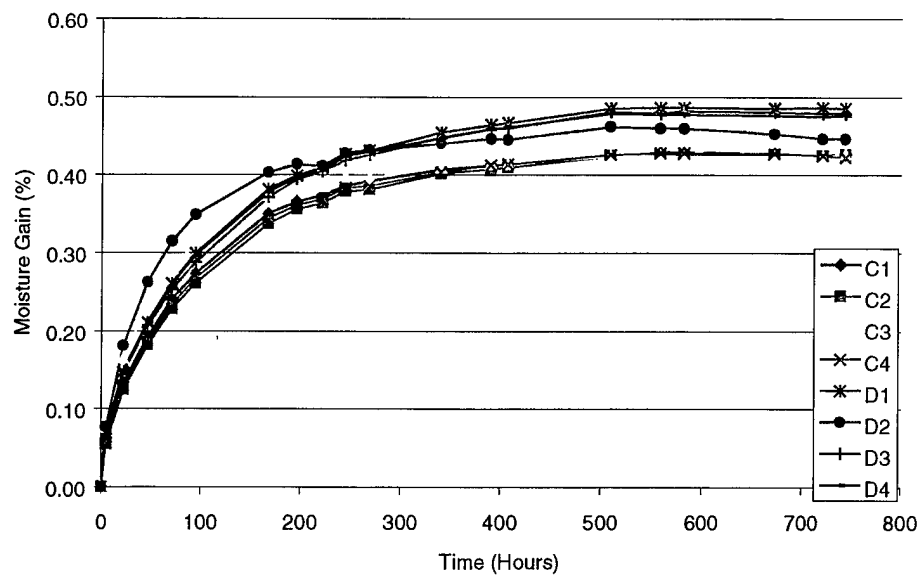


Figure 5. Moisture absorption in AS4/Ultem disks at 35 °C and 98% RH. Group C had no coating, and group D had the primer coating.

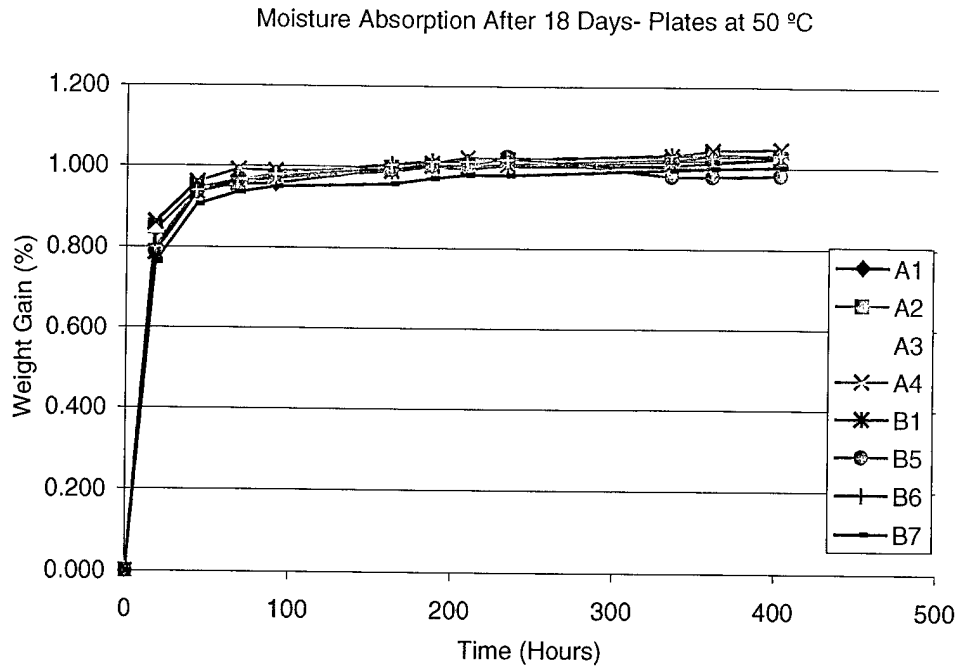


Figure 6. Moisture absorption in T650/1914-4 plates at 50 °C and 98% RH. Group A had the primer coating, and group B had no coating.

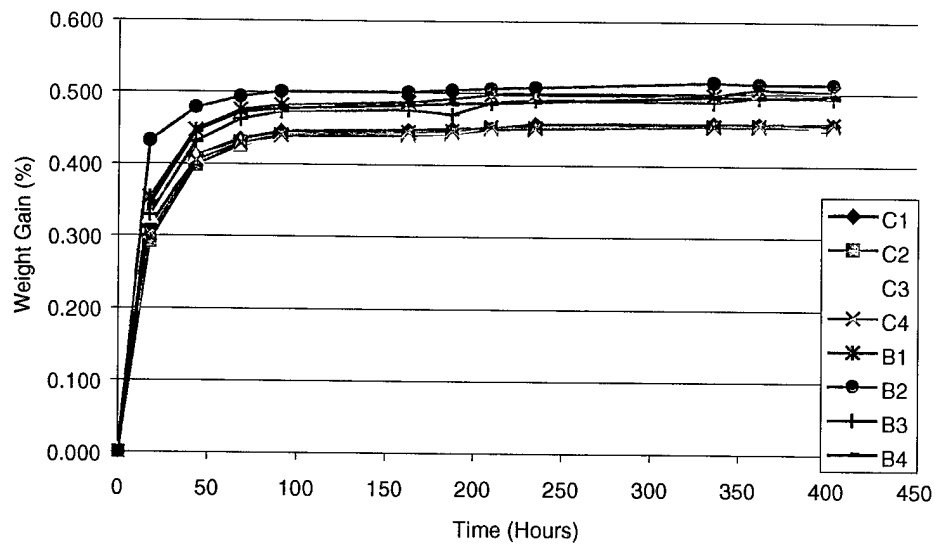


Figure 7. Moisture absorption in AS4/Ultem disks at 50 °C and 98% RH. Group C had no coating, and group B had the primer coating.

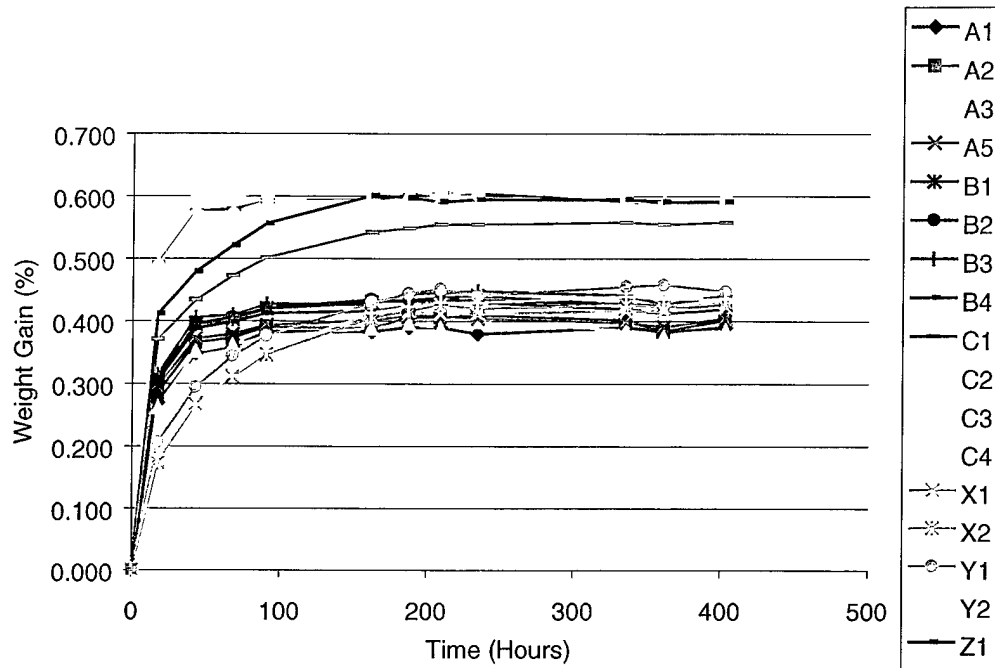


Figure 8. Moisture absorption in AS4/Ultem compression molded bars at 50 °C and 98% RH. None of the specimens in groups A, B, and C had diffusion in the fiber direction. Group A had no coating, group B had Humiseal 2A53 coating, and group C had Siloxirane coating. Groups X, Y, and Z experienced diffusion transverse to the fiber direction. Group X had no coating, group Y had Humiseal 2A53 coating, and group Z had Siloxirane coating.

5. Conclusions

Moisture diffusion measurements have been made for coated and uncoated composite materials. Two substrates were used: T650/1914-4 (a graphite fiber reinforced thermoset epoxy) and AS4/Ultem (a graphite fiber reinforced thermoplastic polymer). The specimens were tested uncoated and coated with three polymer coatings (MIL-P-53030 Primer, Humiseal 2A53 and 2031 Siloxirane). The coatings generally increased the total moisture absorption for the specimens. For the AS4/Ultem bars, anisotropic diffusion constants were measured and diffusion occurs in the fiber direction three times faster than transverse to the fibers.

Table 2. Testing results.

Substrate	Coating	Test Temperature (°F / °C)	No. of Specimens	Specimen Thickness (in)	Standard Deviation	Maximum Moisture Content (%)	Standard Deviation	Effective Diffusion Coefficient (in ² /hr)	Standard Deviation
T650/1914-4 Plates Transverse to Fibers	Primer	95 °F 35 °C	7	2.786E-02	8.522E-04	0.979	0.119	1.682E-06	3.097E-07
T650/1914-4 Plates Transverse to Fibers	None	95 °F 35 °C	6	2.300E-02	1.304E-03	0.906	0.141	3.764E-07	1.269E-07
AS4/Ultem Disks Fiber Direction	None	95 °F 35 °C	4	1.005E-01	1.826E-03	0.425	0.002	7.822E-06	2.341E-06
AS4/Ultem Disks Fiber Direction	Primer	95 °F 35 °C	4	1.083E-01	2.887E-04	0.472	0.017	9.972E-06	1.895E-06
T650/1914-4 Plates Transverse to Fibers	Primer	122 °F 50 °C	4	2.650E-02	1.000E-03	1.072	0.004	4.984E-06	4.731E-07
T650/1914-4 Plates Transverse to Fibers	None	122 °F 50 °C	4	2.150E-02	5.774E-04	1.042	0.022	2.948E-06	2.914E-07
AS4/Ultem Disks Fiber Direction	Primer	122 °F 50 °C	4	1.003E-01	1.708E-03	0.470	0.005	4.860E-05	3.522E-06
AS4/Ultem Disks Fiber Direction	None	122 °F 50 °C	4	1.075E-01	2.380E-03	0.516	0.011	6.121E-05	1.550E-05
AS4/Ultem Bars Fiber Direction	None	122 °F 50 °C	4	9.725E-02	4.193E-03	0.403	0.005	5.074E-05	2.908E-06
AS4/Ultem Bars Fiber Direction	Humiseal	122 °F 50 °C	4	9.875E-02	9.574E-04	0.435	0.004	5.503E-05	2.020E-06
AS4/Ultem Bars Fiber Direction	Siloxirane	122 °F 50 °C	4	1.043E-01	2.630E-03	0.582	0.006	9.280E-05	9.061E-06
AS4/Ultem Bars Transverse to Fibers	None	122 °F 50 °C	2	9.650E-02	2.121E-03	0.436	0.007	1.686E-05	2.565E-07
AS4/Ultem Bars Transverse to Fibers	Humiseal	122 °F 50 °C	2	1.035E-01	6.364E-03	0.457	0.007	2.195E-05	8.319E-08
AS4/Ultem Bars Transverse to Fibers	Siloxirane	122 °F 50 °C	2	1.070E-01	2.828E-03	0.566	0.021	6.138E-05	1.087E-06

6. References

1. Newill, J. F., S. H. McKnight, C. P. R. Hoppel, G. R. Cooper, and M. S. Berman. "Theoretical Evaluation of Moisture Protection Using Coatings." U.S. Army Symposium on Solid Mechanics Proceedings, Myrtle Beach, SC, 14 April 1999.
2. Bogetti T. A., C. P. R. Hoppel, J. F. Newill, J. Elwood, and J. W. Gillespie, Jr. "Moisture Diffusion in a Graphite-Epoxy Composite." *Proceedings of the American Society for Composites Twelfth Technical Conference*, American Society for Composites, pp. 1133-1140, 1997.
3. Hoppel, C. P. R., T. A. Bogetti, and J. F. Newill. "Method of Evaluating Moisture Diffusion Coefficients for Composite Sabots." ARL-TR-1669, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, April 1998.
4. American Society for Testing and Materials. "Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials." ASTM D 5229/D 5229M-92, Philadelphia, PA, 1992.
5. Newill, J. F., G. R. Cooper, S. H. McKnight, and C. P. R. Hoppel. "Analytical Solutions for Coated Substrates Subjected to Transient Boundary Conditions." U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, to be published.
6. Rao, R. M. V. G. K., N. Balasubramanian, and M. Chandra. "Factors Affecting Moisture Absorbtion in Polymer Composites, Part I: Influence of Internal Factors." *Environmental Effects on Composite Materials*, edited by G. S. Springer, vol. 3, pp. 75-88, Lancaster, PA, 1988.

INTENTIONALLY LEFT BLANK.

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	DEFENSE TECHNICAL INFORMATION CENTER DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	HQDA DAMO FDT 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	OSD OUSD(A&T)/ODDDR&E(R) R J TREW THE PENTAGON WASHINGTON DC 20301-7100
1	DPTY CG FOR RDA US ARMY MATERIEL CMD AMCRDA 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN PO BOX 202797 AUSTIN TX 78720-2797
1	DARPA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	US MILITARY ACADEMY MATH SCI CTR OF EXCELLENCE MADN MATH MAJ HUBER THAYER HALL WEST POINT NY 10996-1786
1	DIRECTOR US ARMY RESEARCH LAB AMSRL D D R SMITH 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LAB AMSRL DD 2800 POWDER MILL RD ADELPHI MD 20783-1197

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AI R RECORDS MGMT 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AP 2800 POWDER MILL RD ADELPHI MD 20783-1197
	<u>ABERDEEN PROVING GROUND</u>
4	DIR USARL AMSRL CI LP (BLDG 305)

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CP CA D SNIDER 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB AMSRL OP SD TA 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB AMSRL OP SD TL 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB AMSRL OP SD TP 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR DA OASARDA SARD SO 103 ARMY PENTAGON WASHINGTON DC 20310-0103
1	DPTY ASST SECY FOR R&T SARD TT THE PENTAGON RM 3EA79 WASHINGTON DC 20301-7100
1	COMMANDER US ARMY MATERIEL CMD AMXMI INT 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	COMMANDER US ARMY ARDEC AMSTA AR QAC T C C PATEL PICATINNY ARSENAL NJ 07806-5000

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	COMMANDER US ARMY ARDEC AMSTA AR M D DEMELLA PICATINNY ARSENAL NJ 07806-5000
3	COMMANDER US ARMY ARDEC AMSTA AR FSA A WARNASH B MACHAK M CHIEFA PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR FSP G M SCHIKSNIS D CARLUCCI PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR FSP A P KISATSKY PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR CCH C H CHANIN S CHICO PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR QAC T D RIGOGLIOSO PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR SRE D YEE PICATINNY ARSENAL NJ 07806-5000

NO. OF
COPIES ORGANIZATION

9 COMMANDER
US ARMY ARDEC
AMSTA AR CCH B
P DONADIA
F DONLON
P VALENTI
C KNUTSON
G EUSTICE
S PATEL
G WAGNECZ
R SAYER
F CHANG
PICATINNY ARSENAL NJ
07806-5000

6 COMMANDER
US ARMY ARDEC
AMSTA AR CCL
F PUZYCKI
R MCHUGH
D CONWAY
E JAROSZEWSKI
R SCHLENNER
M CLUNE
PICATINNY ARSENAL NJ
07806-5000

1 COMMANDER
US ARMY ARDEC
AMSTA AR WET
T SACHAR
BLDG 172
PICATINNY ARSENAL NJ
07806-5000

1 COMMANDER
US ARMY ARDEC
AMSTA ASF
PICATINNY ARSENAL NJ
07806-5000

1 US ARMY ARDEC
INTELLIGENCE SPECIALIST
AMSTA AR WEL F
M GUERRIERE
PICATINNY ARSENAL NJ
07806-5000

NO. OF
COPIES ORGANIZATION

11 PM TMA
SFAE GSSC TMA
R MORRIS
C KIMKER
D GUZOWICZ
E KOPACZ
R ROESER
R DARCY
R MCDANOLDS
L D ULISSE
C ROLLER
J MCGREEN
B PATER
PICATINNY ARSENAL NJ
07806-5000

2 PEO FIELD ARTILLERY SYS
SFAE FAS PM
H GOLDMAN
T MCWILLIAMS
PICATINNY ARSENAL NJ
07806-5000

1 COMMANDER
US ARMY ARDEC
AMSTA AR WEA
J BRESCIA
PICATINNY ARSENAL NJ
07806-5000

1 COMMANDER
US ARMY ARDEC
PRODUCTION BASE
MODERN ACTY
AMSMC PBM K
PICATINNY ARSENAL NJ
07806-5000

6 PM SADARM
SFAE GCSS SD
COL B ELLIS
M DEVINE
R KOWALSKI
W DEMASSI
J PRITCHARD
S HROWNACK
PICATINNY ARSENAL NJ
07806-5000

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	COMMANDER US ARMY TACOM PM ABRAMS SFAE ASM AB 6501 ELEVEN MILE RD WARREN MI 48397-5000
3	COMMANDER US ARMY TACOM PM TACTICAL VEHICLES SFAE TVL SFAE TVM SFAE TVH 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM BFVS SFAE ASM BV 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM AFAS SFAE ASM AF 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM RDT&E SFAE GCSS W AB J GODELL 6501 ELEVEN MILE RD WARREN MI 48397-5000
2	COMMANDER US ARMY TACOM PM SURV SYS SFAE ASM SS T DEAN SFAE GCSS W GSI M D COCHRAN 6501 ELEVEN MILE RD WARREN MI 48397-5000

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	COMMANDER US ARMY TACOM PM SURVIVABLE SYSTEMS SFAE GCSS W GSI H M RYZYI 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM BFV SFAE GCSS W BV S DAVIS 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM LIGHT TACTICAL VHCLS AMSTA TR S A J MILLS MS 209 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM GROUND SYSTEMS INTEGRATION SFAE GCSS W GSI R LABATILLE 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM CHIEF ABRAMS TESTING SFAE GCSS W AB QT T KRASKIEWICZ 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM AMSTA SF WARREN MI 48397-5000
1	COMMANDER WATERVLIET ARSENAL SMCWV QAE Q B VANINA BLDG 44 WATERVLIET NY 12189-4050

NO. OF
COPIES ORGANIZATION

15 COMMANDER
US ARMY TACOM
AMSTA TR R
J CHAPIN
R MCCLELLAND
D THOMAS
J BENNETT
D HANSEN
AMSTA JSK
S GOODMAN
J FLORENCE
K IYER
D TEMPLETON
A SCHUMACHER
AMSTA TR D
D OSTBERG
L HINOJOSA
B RAJU
AMSTA CS SF
H HUTCHINSON
F SCHWARZ
WARREN MI 48397-5000

1 COMMANDER
WATERVLIET ARSENAL
SMCWV SPM
T MCCLOSKEY
BLDG 253
WATERVLIET NY 12189-4050

2 TSM ABRAMS
ATZK TS
S JABURG
W MEINSHAUSEN
FT KNOX KY 40121

11 BENET LABORATORIES
AMSTA AR CCB
R FISCELLA
G D ANDREA
E KATHE
M SCAVULO
G SPENCER
P WHEELER
K MINER
J VASILAKIS
G FRIAR
R HASENBEIN
AMSTA CCB R
S SOPOK
WATERVLIET NY 12189-4050

NO. OF
COPIES ORGANIZATION

3 ARMOR SCHOOL
ATZK TD
R BAUEN
J BERG
A POMEY
FT KNOX KY 40121

2 HQ IOC TANK
AMMUNITION TEAM
AMSIO SMT
R CRAWFORD
W HARRIS
ROCK ISLAND IL 61299-6000

1 DIRECTOR
US ARMY AMCOM
SFAE AV RAM TV
D CALDWELL
BLDG 5300
REDSTONE ARSENAL AL
35898

2 COMMANDER
US ARMY AMCOM
AVIATION APPLIED TECH DIR
J SCHUCK
FT EUSTIS VA 23604-5577

1 US ARMY CERL
R LAMPO
2902 NEWMARK DR
CHAMPAIGN IL 61822

4 DIRECTOR
US ARMY CECOM
NIGHT VISION &
ELECTRONIC SENSORS DIR
AMSEL RD NV CM CCD
R ADAMS
R MCLEAN
A YINGST
AMSEL RD NV VISP
E JACOBS
10221 BURBECK RD
FT BELVOIR VA 22060-5806

2 US ARMY CORPS OF ENGINEERS
CERD C
T LIU
CEW ET
T TAN
20 MASS AVE NW
WASHINGTON DC 20314

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	US ARMY COLD REGIONS RSCH & ENGRNG LAB P DUTTA 72 LYME RD HANOVER NH 03755
1	SYSTEM MANAGER ABRAMS ATZK TS LTC J H NUNN BLDG 1002 RM 110 FT KNOX KY 40121
1	USA SBCCOM PM SOLDIER SPT AMSSB PM RSS A J CONNORS KANSAS ST NATICK MA 01760-5057
3	BALLISTICS TEAM AMSSB RIP PHIL CUNNIFF JOHN SONG WALTER ZUKAS KANSAS ST NATICK MA 01760-5057
2	MATERIAL SCIENCE TEAM AMSSB RSS JEAN HERBERT MICHAEL SENNETT KANSAS ST NATICK MA 01760-5057
2	DAVID TAYLOR RESEARCH CTR R ROCKWELL W PHYLLAIER BETHESDA MD 20054-5000
1	OFC OF NAVAL RESEARCH D SIEGEL CODE 351 800 N QUINCY ST ARLINGTON VA 22217-5660
1	NAVAL SURFACE WARFARE CTR DAHLGREN DIV CODE G06 DAHLGREN VA 22448
1	NAVAL SURFACE WARFARE CTR TECH LIBRARY CODE 323 17320 DAHLGREN RD DAHLGREN VA 22448

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
8	DIRECTOR US ARMY NATIONAL GROUND INTELLIGENCE CTR D LEITER M HOLTUS M WOLFE S MINGLEDORF J GASTON W GSTATTENBAUER R WARNER J CRIDER 220 SEVENTH ST NE CHARLOTTESVILLE VA 22091
6	US ARMY SBCCOM SOLDIER SYSTEMS CENTER BALLISTICS TEAM J WARD MARINE CORPS TEAM J MACKIEWICZ BUS AREA ADVOCACY TEAM W HASKELL SSCNC WST W NYKVIST T MERRILL S BEAUDOIN KANSAS ST NATICK MA 01760-5019
9	US ARMY RESEARCH OFC A CROWSON J CHANDRA H EVERETT J PRATER R SINGLETON G ANDERSON D STEPP D KISEROW J CHANG PO BOX 12211 RESEARCH TRIANGLE PARK NC 27709-2211
3	NAVAL RESEARCH LAB I WOLOCK CODE 6383 R BADALIANCE CODE 6304 L GAUSE WASHINGTON DC 20375
1	NAVAL SURFACE WARFARE CTR CRANE DIVISION M JOHNSON CODE 20H4 LOUISVILLE KY 40214-5245

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	COMMANDER NAVAL SURFACE WARFARE CTR CARDEROCK DIVISION R PETERSON CODE 2020 M CRITCHFIELD CODE 1730 BETHESDA MD 20084	1	EXPEDITIONARY WARFARE DIV N85 F SHOUP 2000 NAVY PENTAGON WASHINGTON DC 20350-2000
2	NAVAL SURFACE WARFARE CTR U SORATHIA C WILLIAMS CD 6551 9500 MACARTHUR BLVD WEST BETHESDA MD 20817	1	AFRL MLBC 2941 P ST RM 136 WRIGHT PATTERSON AFB OH 45433-7750
1	DAVID TAYLOR RESEARCH CTR SHIP STRUCTURES & PROTECTION DEPT CODE 1702 BETHESDA MD 20084	1	AFRL MLSS R THOMSON 2179 12TH ST RM 122 WRIGHT PATTERSON AFB OH 45433-7718
8	NAVAL SURFACE WARFARE CTR J FRANCIS CODE G30 D WILSON CODE G32 R D COOPER CODE G32 J FRAYSSE CODE G33 E ROWE CODE G33 T DURAN CODE G33 L DE SIMONE CODE G33 R HUBBARD CODE G33 DAHLGREN VA 22448	2	AFRL F ABRAMS J BROWN BLDG 653 2977 P ST STE 6 WRIGHT PATTERSON AFB OH 45433-7739
1	NAVAL SEA SYSTEMS CMD D LIESE 2531 JEFFERSON DAVIS HWY ARLINGTON VA 22242-5160	1	AFRL MLS OL L COULTER 7278 4TH ST BLDG 100 BAY D HILL AFB UT 84056-5205
1	NAVAL SURFACE WARFARE CTR M LACY CODE B02 17320 DAHLGREN RD DAHLGREN VA 22448	1	OSD JOINT CCD TEST FORCE OSD JCCD R WILLIAMS 3909 HALLS FERRY RD VICKSBURG MS 29180-6199
1	OFC OF NAVAL RES J KELLY 800 NORTH QUINCEY ST ARLINGTON VA 22217-5000	1	DEFENSE NUCLEAR AGENCY INNOVATIVE CONCEPTS DIV 6801 TELEGRAPH RD ALEXANDRIA VA 22310-3398
2	NAVAL SURFACE WARFARE CTR CARDEROCK DIVISION R CRANE CODE 2802 C WILLIAMS CODE 6553 3A LEGGETT CIR BETHESDA MD 20054-5000	1	WATERWAYS EXPERIMENT D SCOTT 3909 HALLS FERRY RD SC C VICKSBURG MS 39180
		2	FAA TECH CENTER P SHYPRYKEVICH AAR 431 ATLANTIC CITY NJ 08405

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
3	DARPA M VANFOSSEN S WAX L CHRISTODOULOU 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
2	SERDP PROGRAM OFC PM P2 C PELLERIN B SMITH 901 N STUART ST STE 303 ARLINGTON VA 22203
1	FAA MIL HDBK 17 CHAIR L ILCEWICZ 1601 LIND AVE SW ANM 115N RESTON VA 98055
1	US DEPT OF ENERGY OFC OF ENVIRONMENTAL MANAGEMENT P RITZCOVAN 19901 GERMANTOWN RD GERMANTOWN MD 20874-1928
1	DIRECTOR LLNL F ADDESSIO MS B216 PO BOX 1633 LOS ALAMOS NM 87545
5	DIRECTOR LLNL R CHRISTENSEN S DETERESA F MAGNESS M FINGER MS 313 M MURPHY L 282 PO BOX 808 LIVERMORE CA 94550
1	OAK RIDGE NATIONAL LABORATORY R M DAVIS PO BOX 2008 OAK RIDGE TN 37831-6195

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	OAK RIDGE NATIONAL LABORATORY C EBERLE MS 8048 PO BOX 2009 OAK RIDGE TN 37831
1	OAK RIDGE NATIONAL LABORATORY C D WARREN MS 8039 PO BOX 2009 OAK RIDGE TN 37922
7	NIST R PARNAS J DUNKERS M VANLANDINGHAM MS 8621 J CHIN MS 8621 D HUNSTON MS 8543 J MARTIN MS 8621 D DUTHINH MS 8611 100 BUREAU DR GAITHERSBURG MD 20899
1	HYDROGEOLOGIC INC SERDP ESTCP SPT OFC S WALSH 1155 HERNDON PKWY STE 900 HERNDON VA 20170
3	DIRECTOR SANDIA NATIONAL LABS APPLIED MECHANICS DEPT DIV 8241 J HANDROCK Y R KAN J LAUFFER PO BOX 969 LIVERMORE CA 94550-0096
3	NASA LANGLEY RSCH CTR AMSRL VS W ELBER MS 266 F BARTLETT JR MS 266 G FARLEY MS 266 HAMPTON VA 23681-0001
1	NASA LANGLEY RSCH CTR T GATES MS 188E HAMPTON VA 23661-3400
1	USDOT FEDERAL RAILRD M FATEH RDV 31 WASHINGTON DC 20590

NO. OF
COPIES ORGANIZATION

1 FHWA
E MUNLEY
6300 GEORGETOWN PIKE
MCLEAN VA 22101

1 CENTRAL INTLLGNC AGENCY
OTI WDAG GT
W L WALTMAN
PO BOX 1925
WASHINGTON DC 20505

1 MARINE CORPS
INTELLIGENCE ACTIVITY
D KOSITZKE
3300 RUSSELL RD STE 250
QUANTICO VA 22134-5011

1 DIRECTOR
NATIONAL GRND INTLLGNC CTR
IANG TMT
220 SEVENTH ST NE
CHARLOTTESVILLE VA
22902-5396

1 DIRECTOR
DEFENSE INTLLGNC AGENCY
TA 5
K CRELLING
WASHINGTON DC 20310

1 GRAPHITE MASTERS INC
J WILLIS
3815 MEDFORD ST
LOS ANGELES CA 90063-1900

1 ADVANCED GLASS FIBER YARNS
T COLLINS
281 SPRING RUN LANE STE A
DOWNINGTON PA 19335

1 COMPOSITE MATERIALS INC
D SHORTT
19105 63 AVE NE
PO BOX 25
ARLINGTON WA 98223

1 COMPOSITE MATERIALS INC
R HOLLAND
11 JEWEL CT
ORINDA CA 94563

NO. OF
COPIES ORGANIZATION

1 COMPOSITE MATERIALS INC
C RILEY
14530 S ANSON AVE
SANTA FE SPRINGS CA 90670

2 COMPOSIX
D BLAKE
L DIXON
120 O NEILL DR
HEBRUN OHIO 43025

4 CYTEC FIBERITE
R DUNNE
D KOHLI
M GILLIO
R MAYHEW
1300 REVOLUTION ST
HAVRE DE GRACE MD 21078

2 SIMULA
J COLTMAN
R HUYETT
10016 S 51ST ST
PHOENIX AZ 85044

1 SIOUX MFG
B KRIEL
PO BOX 400
FT TOTTEN ND 58335

2 PROTECTION MATERIALS INC
M MILLER
F CRILLEY
14000 NW 58 CT
MIAMI LAKES FL 33014

3 FOSTER MILLER
J J GASSNER
M ROYLANCE
W ZUKAS
195 BEAR HILL RD
WALTHAM MA 02354-1196

1 ROM DEVELOPMENT CORP
R O MEARA
136 SWINEBURNE ROW
BRICK MARKET PLACE
NEWPORT RI 02840

1 O GARA HESS & EISENHARDT
M GILLESPIE
9113 LESAINTE DR
FAIRFIELD OH 45014

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	TEXTRON SYSTEMS T FOLTZ M TREASURE 201 LOWELL ST WILMINGTON MA 08870-2941
1	JPS GLASS L CARTER PO BOX 260 SLATER RD SLATER SC 29683
2	MILLIKEN RSCH CORP H KUHN M MACLEOD PO BOX 1926 SPARTANBURG SC 29303
1	CONNEAUGHT INDUSTRIES INC J SANTOS PO BOX 1425 COVENTRY RI 02816
2	BATTELLE NATICK OPNS J CONNORS B HALPIN 209 W CENTRAL ST STE 302 NATICK MA 01760
1	ARMTEC DEFENSE PRODUCTS S DYER 85 901 AVE 53 PO BOX 848 COACHELLA CA 92236
1	GLCC INC J RAY 103 TRADE ZONE DR STE 26C WEST COLUMBIA SC 29170
3	PACIFIC NORTHWEST LAB M SMITH G VAN ARSDALE R SHIPPELL PO BOX 999 RICHLAND WA 99352
2	AMOCO PERFORMANCE PRODUCTS M MICHNO JR J BANISAUKAS 4500 MCGINNIS FERRY RD ALPHARETTA GA 30202-3944

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	SAIC M PALMER 1410 SPRING HILL RD STE 400 MS SH4 5 MCLEAN VA 22102
1	SAIC G CHRYSSOMALLIS 3800 W 80TH ST STE 1090 BLOOMINGTON MN 55431
1	AAI CORPORATION T G STASTNY PO BOX 126 HUNT VALLEY MD 21030-0126
1	APPLIED COMPOSITES W GRISCH 333 NORTH SIXTH ST ST CHARLES IL 60174
3	ALLIANT TECHSYSTEMS INC J CONDON E LYNAM J GERHARD WV01 16 STATE RT 956 PO BOX 210 ROCKET CENTER WV 26726-0210
1	CUSTOM ANALYTICAL ENG SYS INC A ALEXANDER 13000 TENSOR LANE NE FLINTSTONE MD 21530
1	OFC DEPUTY UNDER SEC DFNS J THOMPSON 1745 JEFFERSON DAVIS HWY CRYSTAL SQ 4 STE 501 ARLINGTON VA 22202
1	PROJECTILE TECHNOLOGY INC 515 GILES ST HAVRE DE GRACE MD 21078
1	LORAL VOUGHT SYSTEMS K COOK 1701 W MARSHALL DR GRAND PRAIRIE TX 75051

NO. OF
COPIES ORGANIZATION

3 HEXCEL INC
 R BOE
 PO BOX 18748
 SALT LAKE CITY UT 84118

8 ALLIANT TECHSYSTEMS INC
 C CANDLAND MN11 2830
 C AAKHUS MN11 2830
 B SEE MN11 2439
 N VLAHAKUS MN11 2145
 R DOHRN MN11 2830
 S HAGLUND MN11 2439
 M HISSONG MN11 2830
 D KAMDAR MN11 2830
 600 SECOND ST NE
 HOPKINS MN 55343-8367

5 AEROJET GEN CORP
 D PILLASCH
 T COULTER
 C FLYNN
 D RUBAREZUL
 M GREINER
 1100 WEST HOLLYVALE ST
 AZUSA CA 91702-0296

1 HERCULES INC
 HERCULES PLAZA
 WILMINGTON DE 19894

1 BRIGS COMPANY
 J BACKOFEN
 2668 PETERBOROUGH ST
 HERNDON VA 22071-2443

1 ZERNOW TECHNICAL SERVICES
 L ZERNOW
 425 W BONITA AVE STE 208
 SAN DIMAS CA 91773

2 OLIN CORPORATION
 FLINCHBAUGH DIV
 E STEINER
 B STEWART
 PO BOX 127
 RED LION PA 17356

1 OLIN CORPORATION
 L WHITMORE
 10101 NINTH ST NORTH
 ST PETERSBURG FL 33702

NO. OF
COPIES ORGANIZATION

1 GKN AEROSPACE
 D OLDS
 15 STERLING DR
 WALLINGFORD CT 06492

1 PRATT & WHITNEY
 C WATSON
 400 MAIN ST MS 114 37
 EAST HARTFORD CT 06108

5 SIKORSKY AIRCRAFT
 G JACARUSO
 T CARSTENSAN
 B KAY
 S GARBO MS S330A
 J ADELMANN
 6900 MAIN ST
 PO BOX 9729
 STRATFORD CT 06497-9729

1 AEROSPACE CORP
 G HAWKINS M4 945
 2350 E EL SEGUNDO BLVD
 EL SEGUNDO CA 90245

2 CYTEC FIBERITE
 M LIN
 W WEB
 1440 N KRAEMER BLVD
 ANAHEIM CA 92806

1 HEXCEL
 T BITZER
 11711 DUBLIN BLVD
 DUBLIN CA 94568

1 BOEING
 R BOHLMANN
 PO BOX 516 MC 5021322
 ST LOUIS MO 63166-0516

2 BOEING DFENSE & SPACE GP
 W HAMMOND S 4X55
 J RUSSELL S 4X55
 PO BOX 3707
 SEATTLE WA 98124-2207

2 BOEING ROTORCRAFT
 P MINGURT
 P HANDEL
 800 B PUTNAM BLVD
 WALLINGFORD PA 19086

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	BOEING DOUGLAS PRODUCTS DIV L J HART SMITH 3855 LAKEWOOD BLVD D800 0019 LONG BEACH CA 90846-0001
1	LOCKHEED MARTIN S REEVE 8650 COBB DR D 73 62 MZ 0648 MARIETTA GA 30063-0648
1	LOCKHEED MARTIN SKUNK WORKS D FORTNEY 1011 LOCKHEED WAY PALMDALE CA 93599-2502
1	LOCKHEED MARTIN R FIELDS 1195 IRWIN CT WINTER SPRINGS FL 32708
1	MATERIALS SCIENCES CORP B W ROSEN 500 OFC CENTER DR STE 250 FT WASHINGTON PA 19034
1	NORTHROP GRUMMAN CORP ELECTRONIC SENSORS & SYSTEMS DIV E SCHOCH MS V 16 1745A W NURSERY RD LINTHICUM MD 21090
2	NORTHROP GRUMMAN ENVIRONMENTAL PROGRAMS R OSTERMAN A YEN 8900 E WASHINGTON BLVD PICO RIVERA CA 90660
1	UDLP D MARTIN PO BOX 359 SANTA CLARA CA 95052
1	UDLP G THOMAS PO BOX 58123 SANTA CLARA CA 95052

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	UDLP R BARRETT MAIL DROP M53 V HORVATICH MAIL DROP M53 328 W BROKAW RD SANTA CLARA CA 95052-0359
3	UDLP GROUND SYSTEMS DIVISION M PEDRAZZI MAIL DROP N09 A LEE MAIL DROP N11 M MACLEAN MAIL DROP N06 1205 COLEMAN AVE SANTA CLARA CA 95052
4	UDLP R BRYNSVOLD P JANKE MS 170 4800 EAST RIVER RD MINNEAPOLIS MN 55421-1498
1	GDLS DIVISION D BARTLE PO BOX 1901 WARREN MI 48090
2	GDLS D REES M PASIK PO BOX 2074 WARREN MI 48090-2074
1	GDLS MUSKEGON OPERATIONS W SOMMERS JR 76 GETTY ST MUSKEGON MI 49442
1	GENERAL DYNAMICS AMPHIBIOUS SYS SURVIVABILITY LEAD G WALKER 991 ANNAPOLIS WAY WOODBIDGE VA 22191
6	INST FOR ADVANCED TECH H FAIR I MCNAB P SULLIVAN S BLESS W REINECKE C PERSAD 3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316

<u>NO. OF</u> <u>COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF</u> <u>COPIES</u>	<u>ORGANIZATION</u>
2	CIVIL ENGR RSCH FOUNDATION PRESIDENT H BERNSTEIN R BELLE 1015 15TH ST NW STE 600 WASHINGTON DC 20005	1	UNIV OF WYOMING D ADAMS PO BOX 3295 LARAMIE WY 82071
1	ARROW TECH ASSOC 1233 SHELBURNE RD STE D 8 SOUTH BURLINGTON VT 05403-7700	2	PENN STATE UNIV R MCNITT C BAKIS 212 EARTH ENGR SCIENCES BLDG UNIVERSITY PARK PA 16802
1	R EICHELBERGER CONSULTANT 409 W CATHERINE ST BEL AIR MD 21014-3613	1	PENN STATE UNIV R S ENGEL 245 HAMMOND BLDG UNIVERSITY PARK PA 16801
1	UCLA MANE DEPT ENGR IV H T HAHN LOS ANGELES CA 90024-1597	1	PURDUE UNIV SCHOOL OF AERO & ASTRO C T SUN W LAFAYETTE IN 47907-1282
2	UNIV OF DAYTON RESEARCH INST R Y KIM A K ROY 300 COLLEGE PARK AVE DAYTON OH 45469-0168	1	STANFORD UNIV DEPT OF AERONAUTICS & AEROBALLISTICS S TSAI DURANT BLDG STANFORD CA 94305
1	MIT P LAGACE 77 MASS AVE CAMBRIDGE MA 01887	1	UNIV OF DAYTON J M WHITNEY COLLEGE PARK AVE DAYTON OH 45469-0240
1	IIT RESEARCH CENTER D ROSE 201 MILL ST ROME NY 13440-6916	7	UNIV OF DELAWARE CTR FOR COMPOSITE MTRLs J GILLESPIE M SANTARE G PALMESE S YARLAGADDA S ADVANI D HEIDER D KUKICH 201 SPENCER LABORATORY NEWARK DE 19716
1	GA TECH RSCH INST GA INST OF TCHNLGY P FRIEDERICH ATLANTA GA 30392	1	DEPT OF MATERIALS SCIENCE & ENGINEERING UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN J ECONOMY 1304 WEST GREEN ST 115B URBANA IL 61801
1	MICHIGAN ST UNIV MSM DEPT R AVERILL 3515 EB EAST LANSING MI 48824-1226		
1	UNIV OF KENTUCKY L PENN 763 ANDERSON HALL LEXINGTON KY 40506-0046		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	NORTH CAROLINA STATE UNIV CIVIL ENGINEERING DEPT W RASDORF PO BOX 7908 RALEIGH NC 27696-7908
3	THE UNIV OF TEXAS AT AUSTIN CTR FOR ELECTROMECHANICS J PRICE A WALLS J KITZMILLER 10100 BURNET RD AUSTIN TX 78758-4497
3	VA POLYTECHNICAL INST & STATE UNIV DEPT OF ESM M W HYER K REIFSNIDER R JONES BLACKSBURG VA 24061-0219
1	UNIV OF MARYLAND DEPT OF AEROSPACE ENGNRNG A J VIZZINI COLLEGE PARK MD 20742
1	DREXEL UNIV A S D WANG 32ND & CHESTNUT ST PHILADELPHIA PA 19104
1	SOUTHWEST RSCH INST ENGR & MATL SCIENCES DIV J RIEGEL 6220 CULEBRA RD PO DRAWER 28510 SAN ANTONIO TX 78228-0510

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
	<u>ABERDEEN PROVING GROUND</u>
1	US ARMY MATERIEL SYSTEMS ANALYSIS P DIETZ 392 HOPKINS RD AMXSU TD APG MD 21005-5071
1	DIRECTOR US ARMY RESEARCH LAB AMSRL OP AP L APG MD 21005-5066
106	DIR USARL AMSRL CI AMSRL CI H W STUREK AMSRL CI S A MARK AMSRL CS IO FI M ADAMSON AMSRL SL B J SMITH AMSRL SL BA AMSRL SL BL D BELY R HENRY AMSRL SL BG AMSRL SL I AMSRL WM B A HORST E SCHMIDT AMSRL WM BA F BRANDON AMSRL WM BC P PLOSTINS D LYON J NEWILL S WILKERSON A ZIELINSKI AMSRL WM BD B FORCH R FIFER R PESCE RODRIGUEZ B RICE AMSRL WM BE C LEVERITT D KOOKER AMSRL WM BR C SHOEMAKER J BORNSTEIN

NO. OF
COPIES ORGANIZATION

ABERDEEN PROVING GROUND (CONT)

AMSRL WM M
D VIECHNICKI
G HAGNAUER
J MCCAULEY
B TANNER
AMSRL WM MA
R SHUFORD
P TOUCHET
N BECK TAN
AMSRL WM MA
D FLANAGAN
L GHIORSE
D HARRIS
S MCKNIGHT
P MOY
P PATTERSON
G RODRIGUEZ
A TEETS
R YIN
AMSRL WM MB
B FINK
J BENDER
T BOGETTI
R BOSSOLI
L BURTON
K BOYD
S CORNELISON
P DEHMER
R DOOLEY
W DRYSDALE
G GAZONAS
S GHIORSE
D GRANVILLE
D HOPKINS
C HOPPEL
D HENRY
R KASTE
M KLUSEWITZ
M LEADORE
R LIEB
E RIGAS
J SANDS
D SPAGNUOLO
W SPURGEON
J TZENG
E WETZEL
AMSRL WM MB ALC
A FRYDMAN

NO. OF
COPIES ORGANIZATION

ABERDEEN PROVING GROUND (CONT)

AMSRL WM MC
J BEATTY
E CHIN
J MONTGOMERY
A WERECZCAK
J LASALVIA
J WELLS
AMSRL WM MD
W ROY
S WALSH
AMSRL WM T
B BURNS
AMSRL WM TA
W GILLICH
T HAVEL
J RUNYEON
M BURKINS
E HORWATH
B GOOCH
W BRUCHEY
AMSRL WM TC
R COATES
AMSRL WM TD
A DAS GUPTA
T HADUCH
T MOYNIHAN
F GREGORY
A RAJENDRAN
M RAFTENBERG
M BOTELER
T WEERASOORIYA
D DANDEKAR
A DIETRICH
AMSRL WM TE
A NIILER
J POWELL
AMSRL SS SD
H WALLACE
AMSRL SS SE R
R CHASE
AMSRL SS SE DS
R REYZER
R ATKINSON
AMSRL SE L
R WEINRAUB
J DESMOND
D WOODBURY

NO. OF
COPIES ORGANIZATION

1 LTD
R MARTIN
MERL
TAMWORTH RD
HERTFORD SG13 7DG
UK

1 SMC SCOTLAND
P W LAY
DERA ROSYTH
ROSYTH ROYAL DOCKYARD
DUNFERMLINE FIFE KY 11 2XR
UK

1 CIVIL AVIATION
ADMINISTRATION
T GOTTESMAN
PO BOX 8
BEN GURION INTERNL AIRPORT
LOD 70150
ISRAEL

1 AEROSPATIALE
S ANDRE
A BTE CC RTE MD132
316 ROUTE DE BAYONNE
TOULOUSE 31060
FRANCE

3 DRA FORT HALSTEAD
P N JONES
M HINTON
SEVEN OAKS KENT TN 147BP
UK

1 DEFENSE RESEARCH ESTAB
VALCARTIER
F LESAGE
COURCELETTE QUEBEC COA
IRO CANADA

2 ROYAL MILITARY COLLEGE OF
SCIENCE SHRIVENHAM
D BULMAN
B LAWTON
SWINDON WILTS SN6 8LA
UK

1 ECOLE POLYTECH
J MANSON
DMX LTC
CH 1015 LAUSANNE
SWITZERLAND

NO. OF
COPIES ORGANIZATION

1 SWISS FEDERAL ARMAMENTS
WKS
W LANZ
ALLMENDSTRASSE 86
3602 THUN
SWITZERLAND

1 ISRAEL INST OF
TECHNOLOGY
S BODNER
FACULTY OF
MECHANICAL ENGR
HAIFA 3200
ISRAEL

1 DSTO MATERIALS
RESEARCH LAB
NAVAL PLATFORM
VULNERABILITY
SHIP STRUCTURES & MTRLS DIV
N BURMAN
PO BOX 50
ASCOT VALE VICTORIA
AUSTRALIA 3032

1 ECOLE ROYAL MILITAIRE
E CELENS
AVE DE LA RENAISSANCE 30
1040 BRUXELLE
BELGIQUE

1 DEF RES ESTABLISHMENT
VALCARTIER
A DUPUIS
2459 BOULEVARD PIE XI NORTH
VALCARTIER QUEBEC
CANADA
PO BOX 8800 COURCELETTE
GOA IRO QUEBEC CANADA

1 INSTITUT FRANCO ALLEMAND
DE RECHERCHES DE SAINT LOUIS
DE M GIRAUD
5 RUE DU GENERAL CASSAGNOU
BOITE POSTALE 34
F 68301 SAINT LOUIS CEDEX
FRANCE

1 TNO DEFENSE RESEARCH
I H PASMAN
POSTBUS 6006
2600 JA DELFT
THE NETHERLANDS

NO. OF
COPIES ORGANIZATION

1	TNO PRINS MAURITS LABORATORY R IJSSELSTEIN LANGE KLEIWEG 137 PO BOX 45 2280 AA RIJSWIJK THE NETHERLANDS
2	FOA NATL DEFENSE RESEARCH ESTAB DIR DEPT OF WEAPONS & PROTECTION B JANZON R HOLMLIN S 172 90 STOCKHOLM SWEDEN
2	DEFENSE TECH & PROC AGENCY GROUND I CREWETHER GENERAL HERZOG HAUS 3602 THUN SWITZERLAND
1	MINISTRY OF DEFENCE RAFAEL ARMAMENT DEVELOPMENT AUTH M MAYSELESS PO BOX 2250 HAIFA 31021 ISRAEL
1	DYNAMEC RESEARCH AB AKE PERSSON BOX 201 SE 151 23 SODERTALJE SWEDEN
1	B HIRSCH TACHKEMONY ST 6 NETAMUA 42611 ISRAEL
1	DEUTSCHE AEROSPACE AG DYNAMICS SYSTEMS M HELD PO BOX 1340 D 86523 SCHROBENHAUSEN GERMANY

INTENTIONALLY LEFT BLANK.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project(0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE March 2001		3. REPORT TYPE AND DATES COVERED Final, October 1999 - September 2000
4. TITLE AND SUBTITLE Moisture Absorption of Coated Composite Materials			5. FUNDING NUMBERS 622618AH80	
6. AUTHOR(S) Melissa A. Klusewitz, Christopher P. R. Hoppel, Steven H. McKnight, and James F. Newill				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: AMSRL-WM-MB Aberdeen Proving Ground, MD 21005-5066			8. PERFORMING ORGANIZATION REPORT NUMBER ARL-MR-508	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Program Manager - Tank Main Armament Systems Picatinny Arsenal, NJ 07806-5000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Moisture diffusion measurements were made for coated and uncoated composite materials. Two substrates were used: T650/1914-4 (a graphite fiber reinforced thermoset epoxy) and AS4/Ultem (a graphite fiber reinforced thermoplastic polymer). The specimens were tested uncoated and coated with three polymer coatings-MIL-P-53030 Primer, Humiseal 2A53, and 2031 Siloxirane. The coatings generally absorbed more moisture than the specimens and increased the total moisture absorption for the coated parts. For the AS4/Ultem bars, anisotropic diffusion constants were measured, and diffusion occurs in the fiber direction three times faster than transverse to the fibers.				
14. SUBJECT TERMS composite, moisture, diffusion, coatings			15. NUMBER OF PAGES 34	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED		19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED
				20. LIMITATION OF ABSTRACT UL

INTENTIONALLY LEFT BLANK.

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. ARL Report Number/Author ARL-MR-508 (Klusewitz) Date of Report March 2001

2. Date Report Received _____

3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) _____

4. Specifically, how is the report being used? (Information source, design data, procedure, source of ideas, etc.) _____

5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. _____

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) _____

CURRENT
ADDRESS

Organization

Name

E-mail Name

Street or P.O. Box No.

City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD
ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)

(DO NOT STAPLE)

DEPARTMENT OF THE ARMY

OFFICIAL BUSINESS

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO 0001,APG,MD

POSTAGE WILL BE PAID BY ADDRESSEE

DIRECTOR
US ARMY RESEARCH LABORATORY
ATTN AMSRL WM MB
ABERDEEN PROVING GROUND MD 21005-5069

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES